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ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

REPORT NO. 101
6 November 1952

THE INFLUENCE OF NOISE ON THE VISUAL CONTRAST THRESHOLD*

*Subtask under Human Engineering Studies, AMRL Project No. 6-95-20-001, Subtask, Hearing and Vibration Problems with Mechanized Equipment.

MEDICAL RESEARCH AND DEVELOPMENT BOARD
OFFICE OF THE SURGEON GENERAL
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THE INFLUENCE OF NOISE ON THE VISUAL CONTRAST THRESHOLD*

by

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from

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ABSTRACT

THE INFLUENCE OF NOISE ON THE VISUAL CONTRAST THRESHOLD

OBJECT

This study was designed to test the relative effects of two discrete noise intensities, one high and the other moderate, on the sensitivity for perception of small light differences displayed as small, variable, bright "targets" located upon a constant and less bright "field."

The effect of noise was studied further in relation to the time required to perceive and respond to the visual "target."

RESULTS AND CONCLUSIONS

Under the conditions of this experiment, the visual sensitivity threshold for low brightness differences was not significantly affected by a noise environment of 90 decibels (db) over a two-hour period when these brightness differences were exposed for a period of adequate duration.

A noise environment of 90 db significantly increased the amount of time required to respond to small light differences when these light differences were near the threshold for discrimination.

When an adequate period of time was allowed to make discriminations, the brightness difference thresholds did not differ in absolute value as a function of prolonged noise stimulation. It may be expected from the experimental results that reducing the exposure time of the visual stimuli to be discriminated to some critical range of values would raise the visual threshold under the influence of a higher level of noise.

The significant effect of high-level noise on response time to near-threshold brightness differences did not seem to be functionally related to the overall duration of exposure to the noise. It may be reasonable, from the statistical results obtained in this respect, to lean toward an immediate-sensory-interaction explanation for the influence of noise

rather than toward one which requires accounting for deterioration due to progressive dulling of motivation, fatigue, and the like.

RECOMMENDATIONS

Further research should be carried out to determine if sensitivity for faintly visible targets is significantly affected by intense noise when the time permitted for perceiving the target is varied systematically between upper and lower limits as indicated by the present study.

Effects of noise of higher intensity than that used in the present study should be investigated.

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THE INFLUENCE OF NOISE ON THE VISUAL CONTRAST THRESHOLD

I. INTRODUCTION

Two recent reviews of the literature on effects of high intensity noise on human behavior, Berrien, 1946 (3) and Kryter, 1950 (15), agree in concluding that, although much thought has been devoted to devising means for reducing noises whenever possible, there is but inconclusive experimental evidence for any specific effects of noise on human efficiency. It is probable that the investigations conducted to determine the effects of noise on such aspects of human activity as output, speed of work or vital processes, were limited in one way or another, either because the criteria adopted for evaluating such effects were too variable to yield statistically analyzable results, or because too many non-controllable variables were present in the situation to permit a clear understanding of the results.

Results of numerous experiments of a more basic nature than those reported in the above reviews, and designed to study the effects of sound, usually in the form of tonal stimuli, on basic perceptual processes, show a considerable amount of agreement (5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 19, 20, 21, 23, 24). Most of these studies purport to show definite changes in the perceptual processes studied (5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 19, 23, 24). Of these latter investigations, some indicate changes which can be interpreted as facilitation or enhancement of perceptual acuity (4, 6, 18), while the remainder show both facilitatory and inhibitory effects (1, 7, 8, 9, 10, 11, 12, 13, 17, 21, 22). It may be suggested that the direction of these changes in perceptual processes is a function of the experimental design adopted; the use of different sound intensities and different perceptual processes.

From this, it would appear that the use of less variable criteria might provide a basis for evaluating the effects of noise on some function of the human organism. Perceptual thresholds are normally only subject to minor variations (22). One might hypothesize that variations which do appear reflect quite closely certain states of the organism Since an intense sensory experience, such as a loud noise, may, hypothetically, tend to alter the state of the organism, it might be worth while to investigate the effects of high-level noise through the relative sensitivity of certain perceptual processes. If such an inter-sensory effect were found to operate, presumably at some central perceptual level, it might have important implications for forms of human activity in which certain perceptual processes are required to play a critical role within a situation of extreme noise.

The military field creates numerous practical situations characterized, at least in part, by the above type of sensory relationship. In aircraft operations, certain minute sensory discriminations are called for within an intense noise environment. No less is this true within the armored and mechanized units where frequently observers in armored vehicles are required to make fine visual discriminations, usually while being subjected to engine noises amounting to 90 db and more. This discriminatory function becomes particularly critical under combat when ambient illumination is low, or when the field of vision is obscured by dust, smoke, or fog. Under any of these circumstances, an observer in a full-track vehicle might be required to spot a target object which is only faintly visible. Since the visibility of objects depends in a large part upon perceptible brightness differences between the objects and their background (16), the observer might be required to make what is essentially a near-threshold brightness difference or brightness contrast discrimination. Further, the amount of time consumed by the observer under any form of obscuration in making the target discrimination may be critical.

The experimental questions raised for the present study by the above considerations are: 1) Has noise any effect on the visual contrast threshold? 2) Has noise any effect on the time required to perceive a brightness difference which is near the threshold of discrimination? 3) Are there any effects of noise on the above two functions which may be related to the duration of exposure to the noise?

For purposes of experimental design, the above questions are expressed as null hypotheses:

1. The mean brightness contrast threshold under a condition of high-level noise is not significantly different from the mean brightness contrast threshold under a condition of low-level noise.

2. There is no systematic relationship between the duration of exposure to either high-noise or low-noise conditions and contrast threshold.

3. The mean response time to small brightness contrasts

under a high-level noise condition is not significantly different from the mean response time to small brightness contrasts under a low-level noise condition.

4. There is no systematic relationship between duration of exposure to either high-level noise or low-level noise conditions and response time to small brightness contrasts.

II. METHODS AND PROCEDURES

Apparatus was constructed to furnish the essential elements within a visual task of contrast between target and background brightness. Upon a circular light field with a brightness I, was presented a series of light patches or targets of positive brightness differences dI. dI/ I for each target value can be regarded as the contrast ratio for that particular target value. The threshold contrast ratio, often known as the Weber fraction, dI/It is determined here as that interpolated dI/I value which is discriminated 50 per cent of the time for a given series of repeated random presentations of the dI/I values. This follows the usual procedure for the psychophysical method of constant stimuli.

A. Apparatus

The diagram in Figure 1A gives a schematic view of the apparatus used. A verbal description can best be given by considering separately the visual task and auditory stimulus components:

Visual task: The principal function of the visual stimulus component is production of a uniformly lighted field. This is shown as LF of Figure 1B. The subject sees monocularly a circular area subtending a 20° angle which is evenly illuminated with a brightness I. In the center of the area and delimited by a sharp black circle is a small, circular area subtending an angle of 1° 40' which is the same brightness I. Two fine lines cross this inner circle, dividing it into quadrants designated up, down, right, and left. Within this inner circle appears the target, a small, square patch of light, whose positive brightness difference above the background is designated as dI. The target can be made to appear within any of the four quadrants.

S_1, S_2, and S_3 of figure 1A, are 25-watt, 115-volt, AC Mazda filament lamps. Voltage for these light sources is controlled through a Sorensen voltage regulator. The field brightness I is produced by S_2 and S_3 illuminating spherical, concave surfaces R_2 and R_1, which are painted flat white.

The light sources are placed 37 inches (radial distance) from R_1 and R_2 in order to produce matched, uniformly illuminated surfaces. S_3 is movable for making critical brightness matches of R_1 and R_2. A rod at A provides sliding movement of S_3.

Thus, LF is produced by surface R_1, through the center of which is cut a 1 3/4-inch opening Op, admitting R_2 (small inner circle). A large cross-hair reticle is inserted at Op, quartering the inner circle for purposes of target position identification.

The target is produced by means of a system involving a half-silvered mirror M_1, a diaphragm with an eccentrically-cut target opening O, a field lens FL, an opal glass diffusing filter DF, and a circular filter carrier FW, providing a choice of a calibrated, neutral density filters. Light source S1 is condensed by C, and produces at M_1 a square target image which subtends 10 minutes of arc at the observer's position. A gear mechanism PI enables the experimenter to position the target diaphragm in any of the four quadrants corresponding to up, right, down, or left. The solonoid shutter Sh, through operation of a timer E, permits timed exposure of the target image.

A warning signal WL is provided by means of a small red light patch at the subject's left eye. The subject's response system consists of a pistol-grip switch for the left hand, and a four-position, right-hand switch for identifying the position of the seen target within the inner circle. An electric timer permits measurement of the subject's response time to perceive the target.

The subject's head is immobilized within a flat-black canopy K, with adjustable chin and forehead rests. A three-inch diameter opening at V restricts vision of the subject's right eye to a 20-degree field. Extraneous light is excluded from the R_1 screen by means of a blackened covering placed between K and R_1.

Auditory stimulus: The auditory stimulus consists of tape-recorded tank noise delivered to the subject through headphones. The noise output was checked with a General Radio sound level meter and set at two levels, 90 db and 45 db. The high-level noise (90 db) was chosen as approximating a mean operational noise experienced by personnel in the tank gunner's position. The 45 db noise level was chosen as representative of a moderate noise level. A further use of the low noise level was in masking out possible sound variations within the experimental situation. The 45 db noise level served as the control condition in this study.

B. Experimental Design and Procedure

By means of neutral density filters, eight dI (target) values were produced. These brightnesses measured in foot-lamberts were .0173, .0283, .0388, .0653, .0785, .0946, .1745, .2625. It may be noted that these values do not progress in an arithmetically linear fashion. Because of the practical impossibility of obtaining a series of equal interval filters in terms of transmitted brightness from the filters that are commercially available, equal intervals in terms of filter density were used (Density $= \text{Log} \frac{1}{\text{Transmission}}$). The brightness values obtained above on that basis are linearly related as $\frac{1}{\text{antilog of filter density}}$. Targets were presented upon an I field of 2.275 foot-lamberts. This value was selected as approximating sky brightness near sunset (2). The selection was consistent with the intention of producing a task of maximum difficulty, yet keeping within the limits of daylight vision.

On the basis of an initial (pre-trial) determination of threshold for each subject, a range of five dI values from the available eight was estimated as encompassing the threshold in future determinations. This range was shifted as needed throughout the remainder of the experiment. Each of the five dI values were presented to each subject in random order five times during the course of each eight 12½-minute periods, over a two-hour interval of time. From each of the eight sessions for each subject, a determination of threshold was made by plotting the relationship of number of targets seen out of five exposures to the five filter values presented. Figure 2 illustrates the method with 2 plottings taken at random from the experimental data. A **straight** line was fitted to the plotted points. A line was then drawn vertically from the 2.5, or 50% point, of the frequency axis to intersect this fitted straight line. A density value selected by a horizontal line drawn from this intersection, therefore, represented approximately the interpolated value which would be seen by the observer 50% of the time in a series of 5 presentations. From the density value selected and the known relationship between density and brightness, the threshold contrast (dI/It was determined. Thus, the data from each subject consisted of eight contrast thresholds over a period of two hours, and under either the high-level noise or the low-level noise conditions. Figure 3 shows the design used for allotment of time.

Subjects were instructed to respond immediately upon perceiving the target by squeezing a trigger. A standard electric clock in the response circuit allowed the experimenter to record time from the onset of the target to the subject's response. The duration of the target presentation in all cases was 9 seconds, whether or not the subject responded.

Two series of target presentations were given, each series to 28 subjects. All 56 subjects were members of one battalion stationed at Fort Knox. With all subjects, vision was 20/20 or better, and hearing was normal. Two subjects were run daily, one at 0830 hours and the other at 1330 hours. Subjects in the high-level noise group were given 90 db of tank noise, uninterrupted for a period of 2 hours. Subjects in the control group were given only 45 db continuous noise through the headphones. Before beginning each test, the filters were checked indirectly for calibration by means of a Macbeth Illuminometer with the test plate in a fixed position in the path of the source light. Since the light value at this point was known previously, when the filters were calibrated directly, constancy for the filter values could be maintained by adjusting the light source intensity to match this previously obtained reading. The procedure of calibration required about 15 minutes. Immediately thereafter, the subject was seated at the viewing canopy of the apparatus. The chin and forehead supports were adjusted to give a centered view of the screen and the target reticle. Following this, the instructions in Appendix A were read.

After the instructions, the headphones were placed on the subject and the 45 db of tank noise sounded for the 15 minutes of the pre-trial. All eight target light values were presented five times in random order. At the end of the pre-trial, the headphones were removed and the subject was conducted to another room to wait for the next phase of the experiment.

The correct response frequency data for the eight filter values were plotted to find the contrast threshold. On the basis of the threshold found, five filters for use in the ensuing series were determined. The pre-trial threshold also served as a matching criterion, determining individual assignments to either the low-or high-level noise group. Matching procedures were begun late in the experiment, the first two-thirds of the subjects having been assigned after the pre-trial to either the low- or high-level noise groups on the basis of chance.

Upon returning to the experiment room approximately 10 minutes after the pre-trial, the subject was seated and the necessary positional adjustments were made. No further explanation was given to the high-level noise subjects to account for the greater noise over the previous pre-trial session. During the ensuing two hours, the subject was required to make 200 visual discriminations. As shown in Figure 3, the series was arbitrarily divided into 8 time periods. Between each period of 12½ minutes, a 2½-minute rest interval was given, primarily to forestall tendencies toward sleep or boredom. The headphones were not removed, nor was the auditory stimulation altered, during these rest intervals.

All errors made in locating the target (by means of the quadrant indicator) were counted as not seen. Very few such errors were made, and these were not found to be consistent with any of the experimental variables.

III. RESULTS

Figure 4 shows the relationship of the mean threshold contrast ratios dI/It of low-level noise subjects versus those of the high-level noise for the pre-trial as well as during the two hours' exposure in steps of 15 minutes. The dI/It means are shown in Table I. The time segment data

TABLE 1

MEANS OF THRESHOLD RATIOS (VALUES IN FOOT LAMBERTS) OF LOW-LEVEL NOISE AND HIGH-LEVEL NOISE GROUPS FOR THE PRE-TRIAL AND FOR THE TWO HOURS' CONTINUOUS EXPOSURE TO THE TWO NOISE CONDITIONS IN 15-MINUTE TIME SEGMENTS

	Pre-trial	I	II	III	IV	V	VI	VII	VIII
Low-level Noise	.0270	.0208	.0207	.0205	.0189	.0200	.0190	.0186	.0187
High-level Noise	.0383	.0253	.0251	.0223	.0226	.0208	.0219	.0226	.0208

indicate a higher threshold for the high-level noise group than for the low-level noise group for the entire series. It can be noted that although the pre-trial thresholds are different, perhaps due to imperfect matching, the differences between the two conditions for all duration intervals except the Vth are greater. There appears to be only a slight trend as a function of duration of exposure to the two conditions. Subject means data were entered into a triple classification table and analyzed. In order to reduce labor and facilitate the analysis, the original filter density values representing thresholds were used in the actual computations. This was thought justifiable, since

TABLE 2

THRESHOLDS (FILTER DENSITY VALUES) DETERMINED FOR EACH SUBJECT UNDER TWO NOISE CONDITIONS AND FOR EIGHT 15-MINUTE SEGMENTS OF TIME

	Subjects	Duration of Exposure I	II	III	IV	V	VI	VII	VIII		
		15 min	30 min	45 min	60 min	75 min	90 min	105 min	120 min	Sum	Mean
Low	1	1.82	1.46	1.79	1.67	1.78	1.80	1.85	1.79	13.96	1.74
	2	2.10	2.15	2.15	2.33	2.36	2.18	2.24	2.20	17.71	2.21
	3	2.28	2.30	2.36	2.22	2.33	2.33	2.42	2.39	18.63	2.33
	4	2.08	2.10	2.21	2.18	2.15	2.14	2.10	2.27	17.23	2.15
	5	2.22	2.27	2.20	2.22	2.22	2.36	2.26	2.30	18.05	2.26
	6	2.21	2.09	2.22	2.15	2.06	2.00	1.95	2.08	16.76	2.10
	7	1.79	1.85	1.97	2.06	2.09	2.06	1.97	2.04	15.83	1.98
	8	2.09	1.98	2.02	2.14	2.20	2.04	2.02	2.16	16.65	2.08
	9	1.78	1.80	1.70	1.90	1.86	2.16	1.86	2.00	15.06	1.88
	10	1.96	1.94	1.96	2.00	2.04	1.92	2.02	1.90	15.74	1.97
	11	2.32	2.21	2.20	2.30	2.12	2.20	2.21	2.12	17.68	2.21
	12	2.10	2.06	2.08	2.00	1.86	1.80	1.84	1.76	15.50	1.94
	13	2.12	2.21	2.21	2.16	2.00	2.16	2.18	2.22	17.26	2.16
	14	1.79	1.92	1.84	1.92	2.08	1.91	2.06	1.92	15.44	1.93
	15	2.08	2.09	2.03	1.98	2.21	2.09	2.22	2.14	16.84	2.10
	16	2.14	2.08	2.16	2.16	1.94	1.92	2.04	1.91	16.35	2.04
	17	2.00	2.06	1.92	1.96	1.92	2.10	2.00	2.09	16.05	2.01
	18	1.80	1.86	1.85	1.79	1.85	1.82	1.86	1.92	14.75	1.84
	19	2.12	2.45	2.20	2.42	2.38	2.24	2.34	2.33	18.48	2.31
	20	2.21	2.08	1.80	2.04	2.03	2.10	2.08	2.12	16.46	2.06
	21	1.85	1.97	2.06	2.00	2.00	2.10	2.14	2.09	16.21	2.03
	22	2.09	2.09	2.04	2.09	2.06	2.06	2.15	2.06	16.64	2.08
	23	2.08	1.92	1.78	1.92	2.09	2.09	2.09	2.03	16.00	2.00
	24	2.00	2.14	2.21	2.10	2.00	2.06	2.10	2.09	16.70	2.09
	25	1.91	2.14	2.18	2.30	2.12	2.20	2.21	2.12	17.18	2.15
	26	2.39	2.33	2.45	2.28	2.16	2.27	2.15	2.16	18.19	2.27
	27	2.03	1.90	1.97	2.08	2.00	2.18	2.24	2.06	16.46	2.06
	28	2.20	2.18	2.15	2.18	2.08	2.18	2.08	2.36	17.41	2.18
	Sum	57.56	57.63	57.71	58.55	57.99	58.47	58.68	58.63	465.22	
	Mean	2.06	2.06	2.06	2.09	2.07	2.09	2.10	2.09		
	S.D.	.834	1.014	.928	.917	.790	.852	.780	.849		
High	1	2.22	2.16	2.21	2.12	2.18	2.33	2.26	2.21	17.69	2.21
	2	2.32	2.36	2.34	2.28	2.38	2.32	2.24	2.30	18.54	2.32
	3.	2.15	2.10	2.15	2.10	2.16	2.08	2.12	2.04	16.90	2.11
	4	1.97	2.06	1.97	2.12	2.00	1.97	2.03	1.92	16.04	2.01
	5	2.21	2.28	2.27	2.18	2.28	2.28	2.09	2.22	17.81	2.23
	6	2.09	2.14	2.09	2.14	2.08	2.08	1.98	2.09	16.69	2.09
	7	2.08	1.91	2.00	2.06	2.12	1.97	2.03	2.12	16.29	2.04
	8	1.90	1.88	2.03	2.00	1.88	1.92	2.09	1.97	15.67	1.96
	9	1.97	1.90	1.88	1.96	1.88	2.09	2.20	2.28	16.16	2.02
	10	1.97	2.90	2.15	2.04	2.09	1.98	2.08	2.12	16.52	2.06
	11	2.24	2.27	2.27	2.45	2.24	2.10	2.21	2.26	18.04	2.26
	12	2.15	2.10	2.18	2.04	2.04	2.18	2.16	2.10	16.95	2.12
	13	2.15	2.00	2.08	2.04	1.97	2.06	2.08	2.24	16.62	2.08
	14	1.48	1.54	1.76	1.86	2.24	2.22	1.88	1.92	14.90	1.86
	15	1.78	1.78	1.82	1.68	1.79	1.67	1.66	1.74	13.92	1.74
	16	2.09	2.02	2.18	1.92	2.03	1.82	1.91	1.97	15.94	1.99
	17	2.08	2.00	1.97	2.18	2.26	2.18	2.21	2.18	17.06	2.13
	18	1.88	1.82	1.91	1.62	1.78	1.61	1.73	1.88	14.23	1.78
	19	2.04	2.22	2.24	2.14	2.27	2.14	1.78	2.03	16.86	2.11
	20	2.08	2.33	2.06	2.15	1.98	2.08	2.10	2.18	16.96	2.12
	21	2.00	1.97	2.03	2.02	2.22	2.04	2.08	2.00	16.34	2.04
	22	1.64	1.80	2.06	1.88	1.88	2.03	1.98	1.98	15.25	1.91
	23	1.70	1.70	1.62	1.80	1.78	1.78	1.78	1.78	13.94	1.74
	24	1.76	1.82	1.86	1.88	1.91	2.04	1.97	2.09	15.33	1.92
	25	1.73	1.92	1.92	1.97	2.00	2.09	1.98	2.06	15.67	1.96
	26	2.01	2.00	2.09	2.04	2.10	2.08	2.09	1.96	16.37	2.05
	27	1.82	1.64	1.76	1.94	1.86	1.76	1.84	1.79	14.41	1.80
	28	2.03	1.84	1.97	2.12	2.16	2.15	2.20	2.15	16.62	2.08
	Sum	55.54	55.85	56.87	56.73	57.58	57.05	56.74	57.58	453.72	
	Mean	1.98	1.99	2.03	2.03	2.06	2.04	2.03	2.06		
	S.D.	.950	1.092	.936	.965	.913	.934	.723	.860		

the relationship between density values and dI/I is known. Individual variance was tested as between pairs of matched subjects (16, pp. 295-299). The data which were analyzed are presented in Table 2. As noted above, the raw scores are threshold filter density values.

Table 3 presents the results of the analysis of variance. Considering first the interactions, i.e., low-high by duration of exposure, low-high by matched pairs of individuals and matched pairs by duration, it may be seen that all three are significant at the .001 level of confidence. This suggests that 1) the relationship between high- and low-level noise thresholds varies according to the duration of exposure; 2) the relationship between the thresholds varies from pair to pair of subjects; and 3) the relationship between subject-pairs thresholds varies according to the duration of exposure to the two noise conditions.

TABLE 3
SUMMARY OF RESULTS OF ANALYSIS OF VARIANCE FOR THRESHOLD DATA

Source	Sum of Squares	df	Variance Estimate	Error Term	F	F required for .05# and .001* levels of confidence
Low vs. High	.295	1	.295	Pooled (L-HxD)+(L-HxM)	2.52	4.13#
Duration of Exposure	.159	7	.022	Pooled (L-HxD)+(MxD)	.16	2.05#
Matched pairs of individuals	5.873	27	.218	Pooled (L-HxM)+(MxD)	2.56	1.00*
L - H x D	.760	7	.109	L-HxDxM	21.80	3.50*
L - H x M	3.227	27	.120	L-HxDxM	24.00	1.00*
M x D	2.306	189	.012	L-HxDxM	2.40	1.00*
L - H x D x M	.930	189	.005	---	---	
Total	13.550	447				

The first null hypothesis (see Introduction) was then tested, i.e., that the mean brightness contrast threshold under a condition of high-level noise is not significantly different from the mean brightness contrast threshold under a condition of low-level noise. The variance estimate for L-H was .295. Since both interactions containing the L-H source of variance were significant, the error term for testing differences between low- and high-level noise should be based on a pooling of the two interaction variances. The resulting error term attains a value of .117. The F is equal to .295/.117, or 2.52. This falls short of the 4.17 value necessary for the 5 per cent level of confidence. On this basis, the null hypothesis stated cannot be rejected.

For a test of the second hypothesis, that there is no systematic relationship between the duration of exposure to either high noise or low noise conditions and contrast threshold, the duration variance is tested by the pooled, significant interaction variances Duration x Matched Pairs and L-H x Duration. The resulting F equals .022/.012, or 1.83, which falls below the value required for $P = .05$. The stated hypothesis is therefore not rejectable.

Figure 5 illustrates the relationship of means of response times over the entire course of the experiment for both high- and low-level noise subjects to all target-background ratios (dI/I). The spread line from the plotted means indicates plus and minus 1 standard deviation. It can be noted that variability appears to increase as the dI/I values decrease. Moreover, two other tendencies are observed, 1) mean times in second's increase in a fairly regular relationship with the decrease in dI/I, and 2) with all but the smallest dI/I value the mean times are greater for the high-level noise group.

A similar plot of the pre-trial data shows a considerable amount of variation in the means, nevertheless, the trend indicated in 1), above, is apparent. A "t" test computed between the grand means of "low" (3.71 sec.) versus "high" (3.68 sec.) for the pre-trial data yields a non-significant value of .15. The means of response times were computed for each dI/I value according to time segment for both the "low" and "high" groups. These means are given in Table 4. The triple classification analysis of these data (16, pp. 289-294) is summarized in Table 5. None of the interaction variances are significant. The triple interaction therefore becomes the error term. The F for "low-high" is significant, 10.33, indicating an effect of high-level noise versus low-level noise on the response time to the various targets. In this case, the effect was to increase the response time, as can be seen graphically in Figure 5. The third null hypotheses, i.e., that the mean response time to small brightness contrasts under a high-level noise condition is not significantly different from the mean response time to small brightness contrasts under a low-level noise condition, can be rejected.

TABLE 4

MEANS OF SUBJECT MEAN RESPONSE TIMES TO BRIGHTNESS CONTRAST TARGETS (IN SECONDS) ACCORDING TO TARGET VALUE AND DURATION TIME-SEGMENT

	Duration of Exposure											
	Target I/T Values	I 15 min	II 30 min	III 45 min	IV 60 min	V 75 min	VI 90 min	VII 105 min	VIII 120 min	Sum	Mean	Standard Deviation
Low	.115	1.20	1.26	1.06	1.26	1.36	1.50	1.26	1.30	10.20	1.28	.333
	.077	1.59	1.73	1.55	1.91	1.49	1.47	1.54	1.98	13.26	1.66	.516
	.042	2.94	3.05	2.45	2.96	2.98	3.35	2.62	2.69	23.04	2.88	.747
	.034	3.29	3.18	3.04	2.99	3.23	3.12	3.15	3.08	25.08	3.14	.262
	.029	3.40	3.37	3.86	3.52	3.54	3.76	3.43	3.44	28.32	3.54	.471
	.017	4.44	4.28	3.63	4.06	4.33	4.38	3.82	4.48	33.42	4.18	.823
	.012	4.21	4.30	4.73	4.15	4.43	4.72	3.88	4.65	35.07	4.38	.810
	.008	4.12	5.01	6.03	6.01	4.58	3.66	4.18	4.46	38.05	4.76	2.31
	Sum	25.19	26.18	26.35	26.86	25.94	25.96	23.88	26.08	206.44		
	Mean	3.15	3.27	3.29	3.36	3.24	3.24	2.98	3.26			
	S.D.	3.18	3.42	4.34	3.87	3.34	3.18	2.89	3.28			
High	.115	1.71	1.18	1.67	1.36	1.95	1.71	2.12	1.85	13.55	1.69	.805
	.077	2.10	2.09	1.76	1.97	2.17	2.02	2.04	1.78	15.81	1.99	1.722
	.042	3.52	3.13	3.19	3.00	3.37	3.01	3.41	3.19	25.82	3.23	.501
	.034	3.39	3.26	3.21	3.50	3.08	3.14	3.44	3.21	26.23	3.28	.394
	.029	3.76	3.58	3.67	3.89	3.64	3.93	3.79	3.80	30.06	3.76	.321
	.017	3.94	4.55	4.63	4.69	4.80	4.85	5.27	5.37	38.10	4.76	1.176
	.012	4.21	3.77	3.90	5.12	5.08	5.59	4.77	4.50	36.94	4.62	1.688
	.008	1.55	4.42	5.90	3.98	4.19	5.20	5.27	5.38	35.89	4.49	3.591
	Sum	24.18	25.98	27.93	27.51	28.28	29.45	30.11	29.06	222.50		
	Mean	3.02	3.25	3.49	3.44	3.54	3.68	3.76	3.63			
	S.D.	2.81	3.01	3.71	3.40	3.01	3.84	3.38	3.73			

TABLE 5

SUMMARY OF RESULTS OF ANALYSIS OF VARIANCE FOR RESPONSE TIME DATA

Source	Sum of Squares	df	Variance Estimate	Error Term	F	F required for .05# and .01* levels of confidence
Low vs. High	2.015	1	2.015	L-HxDxT	10.33	7.17*
Duration of Exposure	1.700	7	.243	L-HxDxT	1.25	2.20#
Targets	163.261	7	23.323	L-HxDxT	119.60	3.02*
L - H x D	2.318	7	.331	L-HxDxT	1.70	2.20#
L - H x T	1.759	7	.251	L-HxDxT	1.29	2.20#
T x D	12.735	49	.260	L-HxDxT	1.33	1.60#
L - H x D x T	9.559	49	.195	---	---	
Total	193.347	127				

The F for response time differences between target brightnesses is quite significant, 119.60. However, no generalization about target mean differences can be made on the basis of the analysis, since a Bartlett test shows the variances of the target means to be non-homogeneous. Duration of exposure to either the "high" or "low" conditions appears to have no reliable effect on the response time as shown by an F of 1.25. Therefore, the fourth null hypothesis, that there is no systematic relationship between duation of exposure to either high-level noise or low-level noise conditions and response time to small brightness contrasts, cannot be rejected. The latter results seem to suggest an immediate noise-threshold interaction rather than a progressive deterioration or change with duration of exposure to noise conditions.

IV. DISCUSSION

This study has demonstrated that within the limited conditions imposed, namely, 1) when the adapting brightness level is moderately low or approximating the brightness of the sky shortly after sunset, 2) when the target to be perceived and fired upon is brighter than the background and subtending only 10 minutes of arc, 3) when the target is to be located within a small, designated spatial framework, and 4) when the target exposure time is a constant of 9 seconds, the sounds of a tank engine emitting 90 db as opposed to tank engine sounds of 45 db may produce no significant differential effects on the just-noticeable difference between the target and background brightnesses. The slight, statistically insignificant, difference found between these two conditions, however, is in the direction of raising the threshold during intense noise.

An observation can be made regarding target exposure time as a factor in the perception of these small light differences. Judging from the results shown in Figure 5, it would appear that nine seconds was more than enough time to perceive, assuming a given sensitivity. Even the faintest light target, represented by the dI/I value of .008, was responded to most of the time within 5.5 seconds. Because of the above noted experimental circumstance, it is likely that visual sensitivity alone, which has been shown to be insignificantly affected by a high noise level, has determined the percentage of light targets seen and therefore the threshold. The results of analyzing mean response time for the eight light targets clearly indicate that more time is required to respond, and presumably to perceive, all but one of the targets (Fig.5) when an intense noise is presented during the visual task. From this it follows that, although the contrast thresholds between high-level noise and low-level noise were only very slightly different, more time would be required to perceive a threshold light difference under high-level noise.

It is conceivable that a critical target exposure time could be determined which would permit perceiving a brightness difference which was just above sensitivity threshold under low-level noise conditions, but which would not permit seeing the same brightness difference under high-level noise conditions owing to the influence of noise on the time required for seeing. The above suggests further experimentation in which exposure time for all targets would be systematically varied within the range of means obtained in the present study, i.e., approximately 5.5 seconds to 1.0 seconds. It may be reasonable to expect that for some particular exposure time the two potential factors of 1) time required to see target, and 2) visual sensitivity, as they relate to the variable of auditory stimulation, may interact to yield a significantly higher contrast threshold for a high noise condition than for a low noise condition.

Research of the general type reviewed by Berrien (3) and Kryter (15) suggest, on the whole, that deleterious effects of noise are progressive, in the sense that fatigue, dulling of motivation, and like factors, play a greater part in reducing output efficiency as a positive function of duration of exposure to the noise. The more basic studies noted in the introduction suggest, on the other hand, certain immediate effects of noise stimulation upon performance of another sensory modality. The results attained in the present study seem to conform to the general findings of the latter type of experimentation in that significant differential effects of noise on response time are not related to the overall duration of exposure to the noise. These differential effects in this study are present in the first 15 minutes of exposure to practically the same extent that they are after 2 hours of exposure.

Insofar as the results attained can be projected to a realistic situation of tank gunnery operation, it may be said that the intense noise concomitant with such operation may act as a detrimental factor in the perception of targets only faintly visible to an observer in the gunner's position.

Another difference between the conditions of this experiment and a field situation has to do with the relationship between the target and the background. Since one probably rarely finds a target which is brighter than the surrounding field, a criticism might be offered in this respect. A reply to this criticism may be given from a study by Blackwell (4) in which an extensive investigation was conducted in contrast thresholds with both positive (target brighter than background) and negative (target darker than background) stimuli. Blackwell reports that there is evidence that negative stimuli are equivalent to positive stimuli of equivalent area and contrast. The exception to this is in the case of large stimuli and low background brightnesses where consistently lower thresholds were found for negative stimuli. The background brightness and stimulus (target) as used in the present study meet the conditions in Blackwell's study showing equivalence. This means that even though the target in our study had been darker than the background, and hence more like a field situation where a target object (darker--enemy tank, gun emplacement, etc.) may be obscured by smoke or fog, the thresholds would not be expected to differ in absolute value from the values obtained in the present study.

Another artificiality which needs some explanation is the presentation of the light target always within a designated, relatively small area. It must be remembered that this target is still not at the intersection of the cross-hair reticle, and hence needs to be located before properly sighted for firing. In general, the stimulus presented to the observer in this experiment corresponds visually to the situation the gunner might find himself in following the tank commander's initial traversing of the gun upon a target.

V. CONCLUSIONS

Under the conditions of this experiment, visual sensitivity for small brightness differences is not significantly affected by an intense noise environment over a time period of two hours when these brightness differences are exposed to the subject for 9 seconds. Most subjects were able to respond correctly within 5.5 seconds to the smallest brightness difference presented.

An intense noise environment significantly increases the amount of time required to respond to faint light differences when these light differernces are near the threshold for discrimination.

Although brightness difference thresholds do not differ in absolute value as a function of noise stimulation when an adequate period of time is allowed to make discriminations, it may be expected that reducing the time permitted for discrimination to certain critical values would increase the visual threshold under the influence of high-level noise.

The significant effect of high-level noise on response time to near-threshold brightness differences does not seem to be related to the overall duration of exposure to the noise. It may be tenable, from the statistical results obtained in this respect, to lean toward an immediate sensory-interaction explanation for the influence of noise on response time rather than toward one which needs to account for deterioration due to progressive dulling of motivation or fatigue.

VI. RECOMMENDATIONS

Further research should be carried out to determine if sensitivity for faintly visible targets is significantly affected by intense noise when the time permitted for perceiving the target is varied systematically between limits indicated by the present study.

It is recommended that immediate-sensory-interaction be further investigated.

Effects of noise of higher intensity than that used in the present study should be investigated.

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APPENDIX A

Instructions to Subjects

You are seated at a tank gunner's controls. Before you, through the right eye, is a view of the outside through the telescope. Imagine the bright area you see is the sky as it would appear around sunset. We left out the ground and horizon line, but you can imagine a horizon somewhere below the center of your view, if you like. The circle and cross-hair in the exact center is a sighting reticle. A far-away object suddenly appears within the sighting circle (target presented). As I will show you, this object may appear at several points around the point where the cross-hairs meet. (Demonstrated).

You are on a combat mission and your specific task is to fire on a single type of target. This target appears to you through the telescope as a small, bright object in the distance. The task has been made very simple. You don't have to worry about the range, and the target will always appear within your sights, though only for a short time. Besides, this target will appear many times. Sometimes it will be bright enough to see without too much trouble, but at other times it will be very difficult to see. In either case, you will have to do your best to see it and fire upon it before it is gone (pistol grip at left hand demonstrated). You remember I said that the target might appear in a number of places around the point where the cross-hairs meet. It will actually appear at only four possible places, either up, down, right, or left. (Demonstrated).

Here is what you will have to do. As soon as the red light appears in your left eye, shift your eyes from whatever they are doing to the sighting circle. Within a few seconds the target will appear. It may be very dim. Find it as quickly as you can and fire at it. If you think you see the target you may fire. If you do not see it you need not fire. Right after you do this, move the indicator post at your right to the position corresponding to where you saw the target, either right, left, up, or down. Remember that you only have a few seconds to fire upon the target before it disappears. A few moments after the target disappears, the red light will flash again and you will go through the same performance in this way a great many times.

Throughout the entire task you will wear headphones, through which you will hear the noise of a tank. I will touch you on the shoulder from time to time, indicating that you can take your head away from the chin rest and look around to rest your eyes. During these short rest periods, do not remove your headphones. In about 15 minutes from now you will have about 10 minutes break for a smoke, etc. After that, return here.

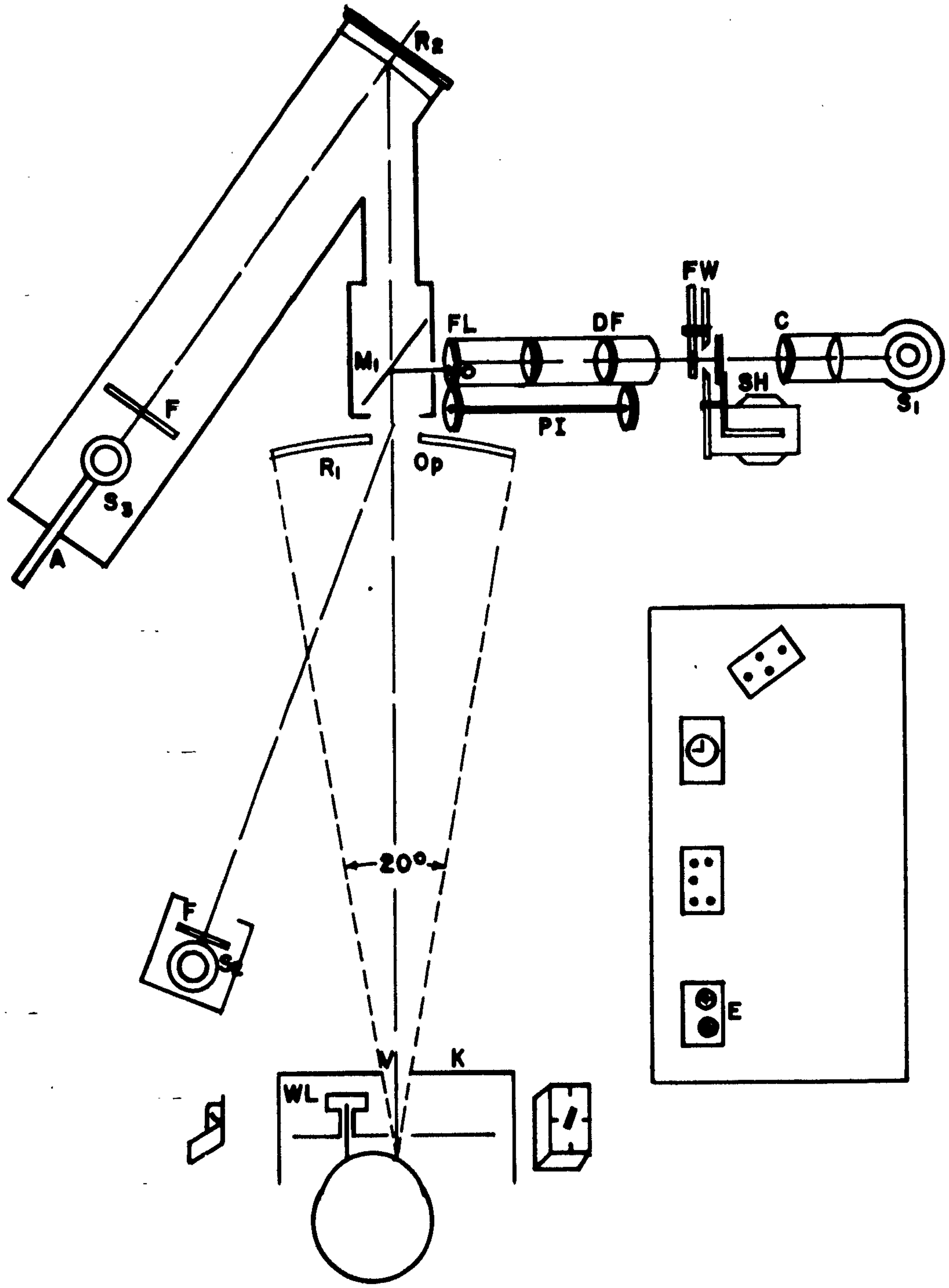

FIGURE 1A.— SCHEMATIC VIEW OF APPARATUS

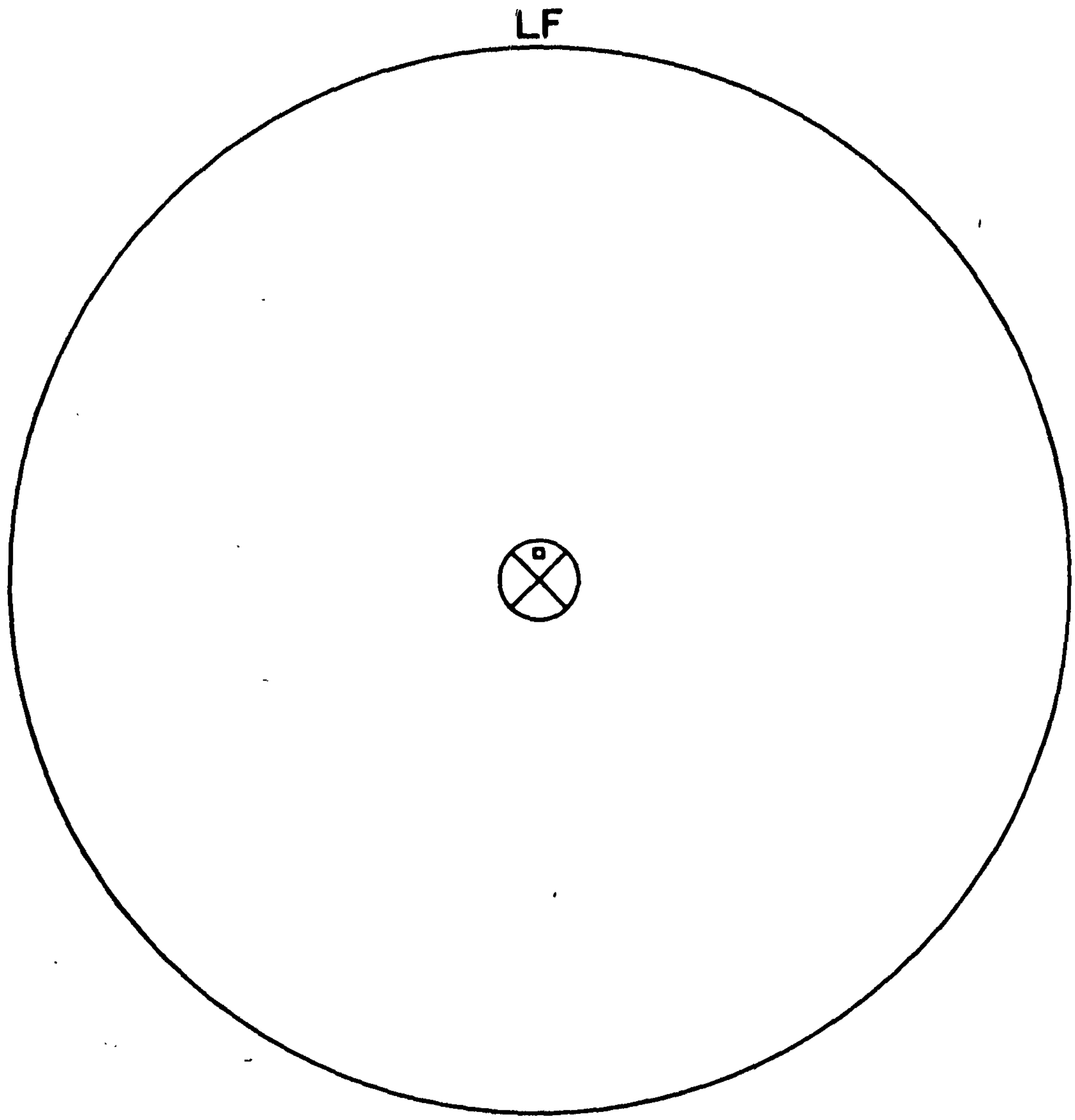

FIGURE 1B - UNIFORMLY ILLUMINATED FIELD VIEWED MONOCULARLY BY OBSERVER. TOTAL AREA IS THAT SUBTENDED BY A 20° ANGLE. IN THE MIDDLE IS A RETICLE OF THE SIZE SUBTENDED BY 1° 40' OF ARC. THE TARGET IS A SMALL SQUARE PATCH OF LIGHT WHICH CAN APPEAR IN ANY OF THE FOUR QUADRANTS OF THE RETICLE.

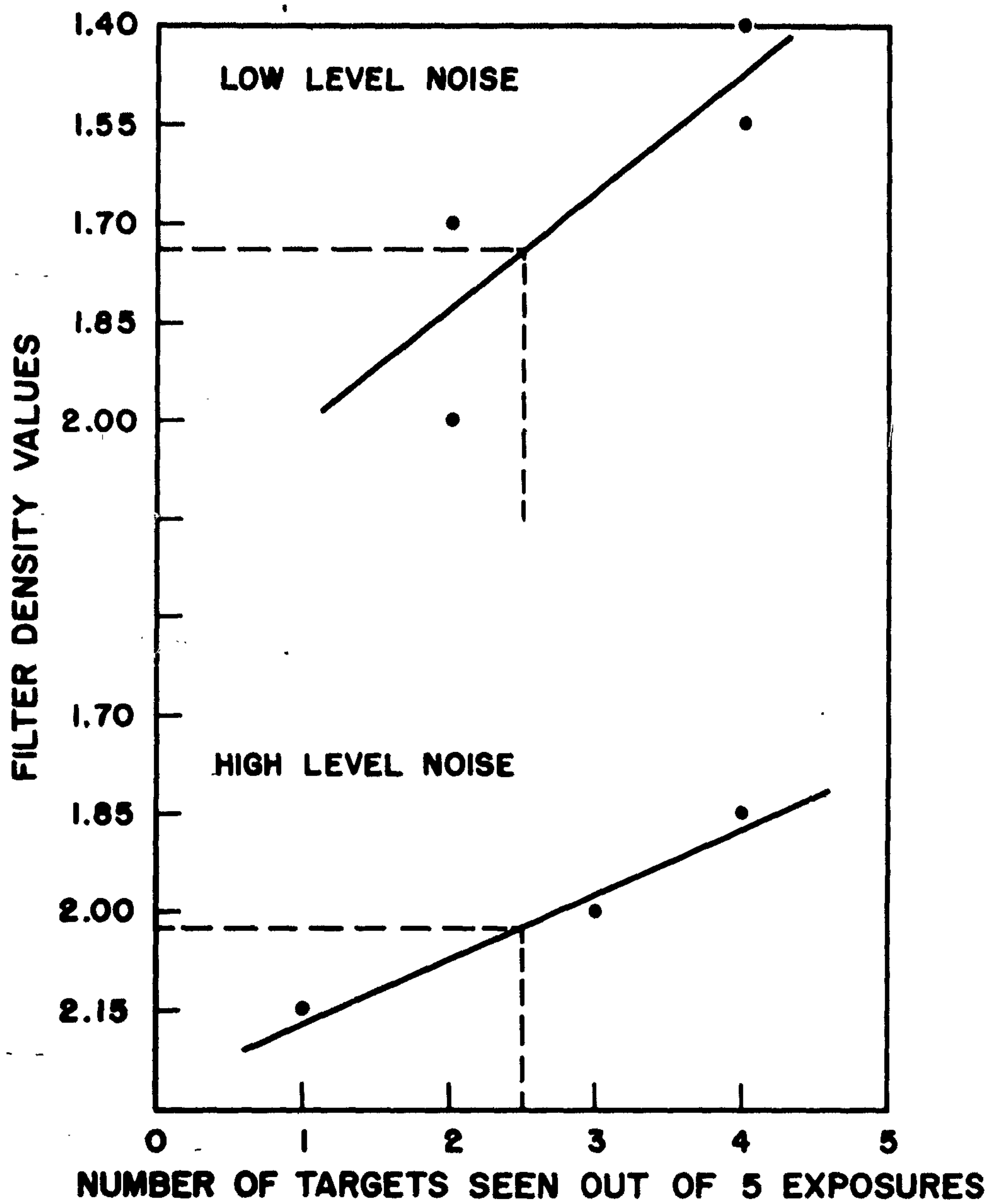

FIGURE 2.- TYPICAL THRESHOLD PLOTS.

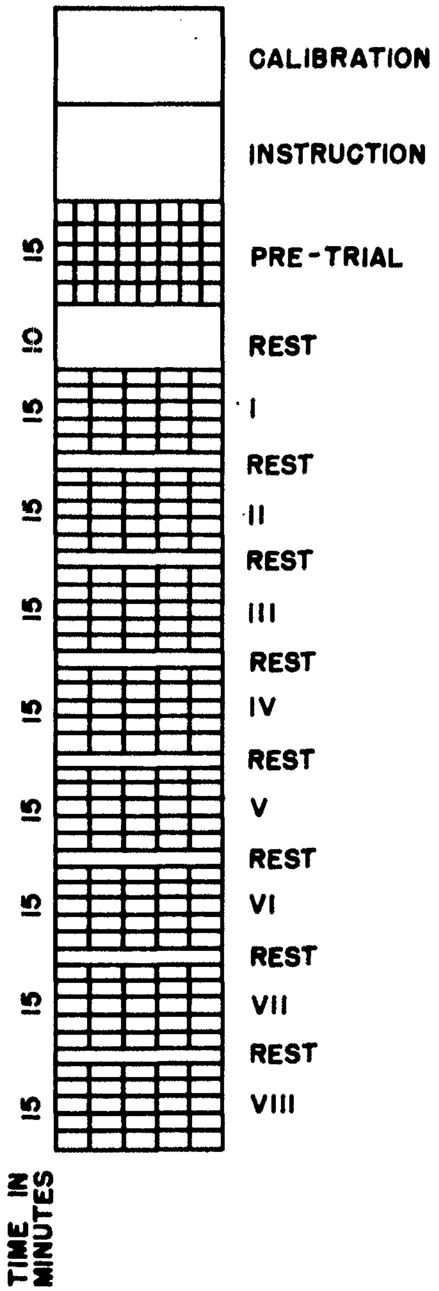

FIGURE 3 - SCALE ILLUSTRATING ALLOTMENT OF TIME FOR SERIES OF TRIALS FOR BOTH HIGH-LEVEL NOISE AND LOW-LEVEL NOISE CONDITIONS.

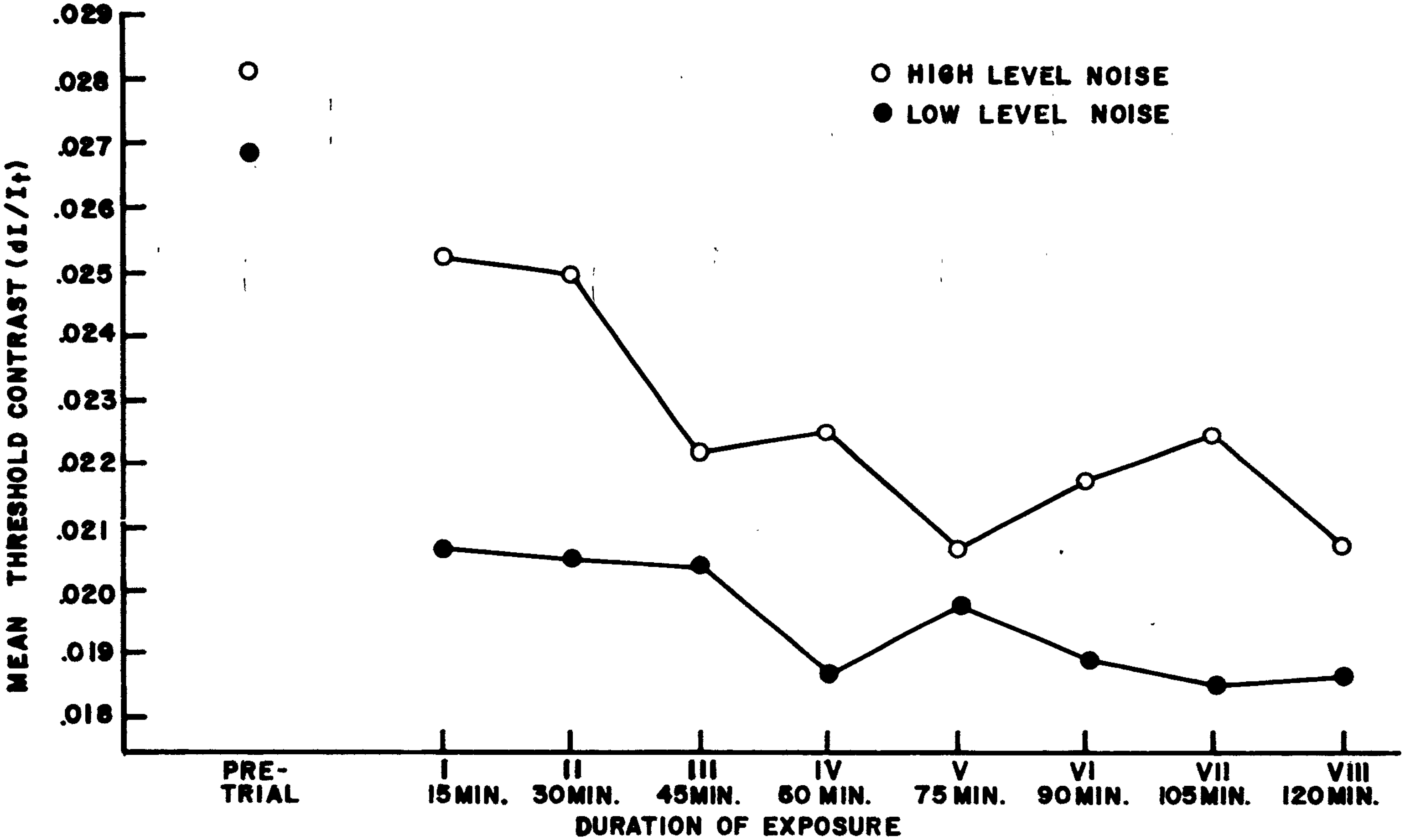

FIGURE 4.- VISUAL THRESHOLD DATA SHOWING THE RELATIONSHIP OF MEAN THRESHOLDS UNDER LOW-LEVEL NOISE TO MEAN THRESHOLD UNDER HIGH-LEVEL NOISE FOR THE PRE-TRIAL AND FOR TWO HOURS' EXPOSURE IN STEPS OF 15 MINUTES.

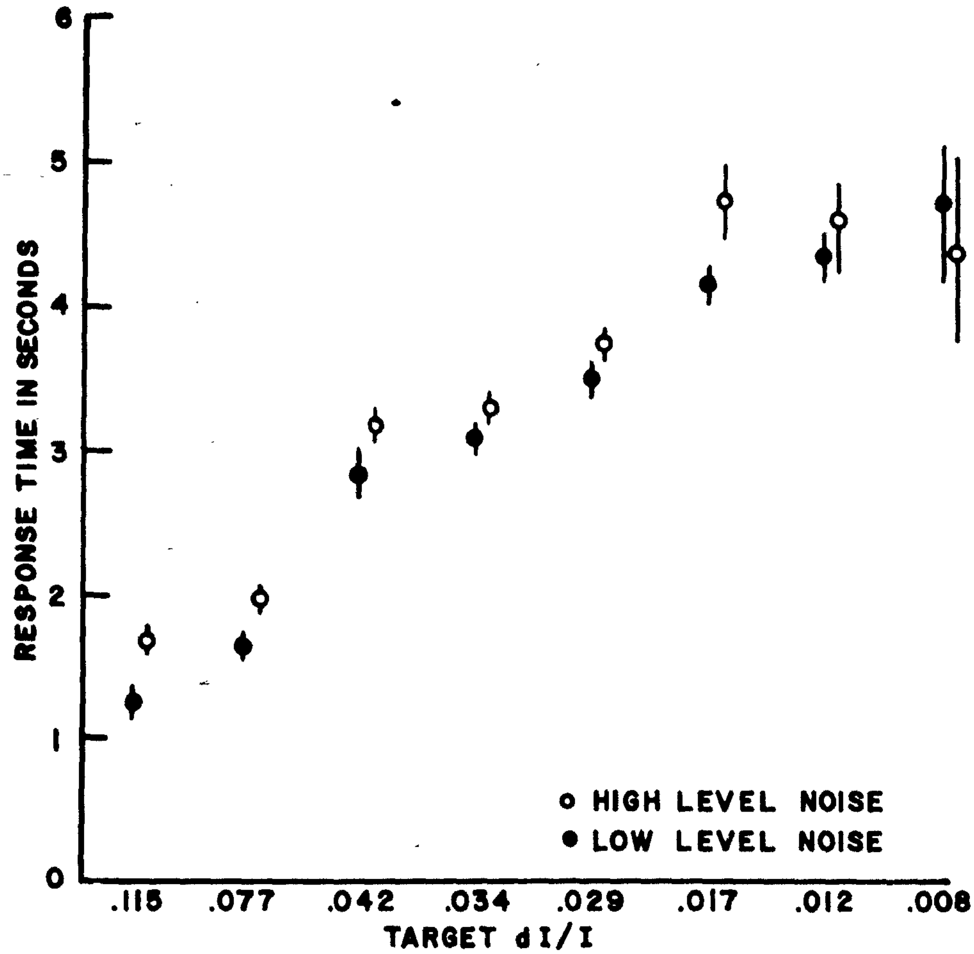

FIGURE 5.—RESPONSE TIME DATA SHOWING THE RELATIONSHIP OF RESPONSE TIMES OVER THE ENTIRE COURSE OF THE EXPERIMENT FOR BOTH HIGH AND LOW LEVEL NOISE SUBJECTS TO ALL TARGET-BACKGROUND RATIOS (dI/I).

THE SPREAD LINE FROM THE PLOTTED MEAN INDICATES PLUS AND MINUS ONE STANDARD DEVIATION.